



STUDIES OF HEAVY ION TRACKS IN NUCLEAR EMULSION

Lars Jacobsson

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Akademisk avhandling som för avläggande av filosofie
doktorsexamen vid matematisk-naturvetenskapliga
fakulteten vid universitetet i Lund kommer att offentligen
försvaras å Fysiska institutionens föreläsningssal B,
fredagen den 20 maj 1977, kl. 10.15.

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When a charged particle passes through a nuclear emulsion, energy is delivered to the silver bromide grains around the particle path. If the energy absorbed in a grain is sufficiently great, a silver grain appears after the development. The distribution of silver grains around the path forms a track, the width and structure of which depends on the charge, the velocity of the particle, and the sensitivity of the emulsion. The width and the structure of the track can be studied by means of photometric measurements. This thesis treats such measurements as have been used both for testing a track formation theory and for identifying particles.

The track formation theory is based on the spatial distribution of the ionization energy around the particle path. The theory is of importance for a positive identification of particles, but it also has applications in radiation biology.

Both charge and mass are possible to determine from track width measurements of particles stopping in the emulsion. Here the method is used in an investigation of the isotopic composition of the nitrogen and oxygen nuclei in the cosmic radiation.

In this thesis the following three publications have been included:

I

A photometer for profile measurements and charge identification on short tracks of heavy nuclei stopping in nuclear emulsion.

Nucl. Instr. and Meth. 112, 575 (1973).

(In collaboration with G. Jönsson, K. Söderström and H. Håkansson)

II

The energy dose concept applied to heavy ion tracks in nuclear emulsion.

Radiation Effects 22, 123 (1974).

(In collaboration with R. Rosander).

III

A measurement in nuclear emulsion of the isotopic abundance of cosmic ray nitrogen and oxygen.

Cosmic and Subatomic Physics Report, LUIP 7702, (1977).

Reports were given at:

- 1) The Conference of the Swedish National Committee for Physics, Lund, Sweden, 1973.
- 2) The VIIIth International Conference on Nuclear Photography and Solid State Track Detectors, Bucharest, Romania, 1972.
- 3) The Conference of the Swedish National Committee for Physics, Gothenburg, Sweden, 1975.
- 4) The 14th International Cosmic Ray Conference, Munich, Fed. Rep. Germany, 1975.
- 5) The Vth European Cosmic Ray Symposium, Leeds, England, 1976.

In Paper I the construction of a nuclear track photometer is described. The photometer can be used both for a detailed study of track structure and for the determination of the charge and mass of stopping particles. The photometer consists of an optical instrument which includes a narrow slit and a revolving mirror system together with an electronic part registering light absorption profiles of track segments. The profiles are registered either with a pen recorder or in digitalized form on paper tape. A test measurement shows that the standard deviation in the charge determination of tracks of very short length ($= 50 \mu\text{m}$) is about 2 charge units for iron nuclei and about 1 charge unit for carbon nuclei.

In Paper II a comparison is made between light absorption profiles of heavy ion tracks and a theory for track formation. The tracks are produced by stopping cosmic ray particles with $6 \leq Z \leq 26$. The measurements cover the residual range interval $0 < R \leq 1000 \mu\text{m}$, implying ion velocities below 0.33 c. Two types of emulsion with different sensitivity, Ilford G5 and Ilford K2, have been investigated. The experimental track widths are compared with the theoretical, calculated distribution of the energy dose around the path of a moving ion. The dose distribution has been calculated according to the formalism of the track formation theory, developed by Katz and co-workers (1969, 1972). The theory gives quite a good description of the track widths for the low-sensitive Ilford K2 emulsion. As regards the measurements in the more sensitive Ilford G5 emulsion, the agreement is not so good between experimental and theoretical widths.

Paper III describes a measurement of track widths, undertaken in order to identify the isotopes of cosmic ray nitrogen and

oxygen. A stack of 61 Ilford G5 emulsions was exposed in a balloon flight in northern Canada. Track widths of particles which had stopped in the stack were measured with a photometer of a type described by Jönsson et al. (1970). After corrections for different emulsion and measuring effects, relative mass values are calculated from the data of track widths. The expected standard deviation in the mass determination is calculated to 0.46 AMU for nitrogen and 0.50 AMU for oxygen. These values are in good agreement with the widths of the mass distributions obtained. In order to obtain a firm interpretation of the mass distribution of nitrogen, an absolute calibration of the mass scale is made. The calibration is based on relations between track width and a parameter for the energy loss, REL (Barkas, 1963). This parameter considers only energy transfers less than a fixed maximum value. The accuracy in the mass calibration is estimated to ± 0.1 AMU. The following results of the isotopic composition are obtained:

$$^{15}\text{N}/\text{N} = 0.33 \pm 0.09$$

$$^{17}\text{O}/\text{O} = 0.05 \pm 0.03$$

$$^{18}\text{O}/\text{O} = 0.08 \pm 0.03$$

These ratios are in agreement with the results from some other investigations. The ratio for nitrogen indicates that nitrogen is present in the source of radiation in approximately the same amounts as in the solar system. The composition of the oxygen isotopes shows that the heavy isotopes ^{17}O and ^{18}O can only be present in the source in very small amounts.

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